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Web service based spatial forest information system using an open source software approach

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Abstract: For technical and other reasons there is a dilemma that data providers cannot find an appropriate way to redistribute spatial forest data and data users who need spatial data cannot access and integrate available forest resources information. To overcome this dilemma, this paper proposed a spatial forest information system based on Web service using an open source software approach. With Web service based architecture, the system can enable interoperability, integrate Web services from other application servers, reuse codes, and shorten the development time and cost. At the same time, it is possible to extend the local system to a regional or national spatial forest information system. The growth of Open Source Software (OSS) provides an alternative choice to proprietary software for operating systems, web servers, Web-based GIS applications and database management systems. Using open source software to develop spatial forest information systems can greatly reduce the cost while providing high performance and sharing spatial forest information. We chose open source software to build a prototype system for Xixia County, Henan Province, China. By integrating OSS packages Deegree and UMN MapServer which are compliant to the OGC open specifications, the prototype system enables users to access spatial forest information and travelling information of Xixia County which come from two different data servers via a standard Web browser and promotes spatial forest information sharing.

Keywords: Web service; spatial forest information system; Open Source Software; Deegree; UMN MapServer

Introduction

Forests have an important effect on the environment of human living, and more and more people and organizations pay attention to forest resources information. To efficiently manage forests requires forest managers to acquire historic and up-to-date spatial forest data and analyze them in order to make practical and sustainable forest management plans. Because of periodic inventories and the application of remote sensing, a large amount of spatial forest data has been collected and stored in different formats. The technical managers can manage and analyze these data, and show the spatial relationships between forests, land formations, waterways, topography, human settlements and other landscape features by using Geographic Information System (GIS) software. GIS has been an important tool for forest resources management.

Although GIS improves forest resources management including data operation and analysis, and benefits to monitoring, planning and other activities, it has three main limitations:

(1) It is a monolithic, stand-alone, mostly proprietary system: only a restricted number of technicians and managers can access the data. On the one hand, there are a lot of spatial forest data stored in different formats and the data providers cannot find appropriate ways to redistribute them; on the other hand, data users who need spatial forest information cannot access and utilize these data. The valuable spatial forest data cannot be fully used while recollecting spatial forest data is a labor-intensive and cost-expensive work, causing redundant data construction.

(2) There are many GIS software products provided by various GIS vendors, but different GIS systems are not necessarily interoperable because they adopted different data models and data structures. Existing GIS systems cannot use and process data from other GIS systems without data conversion.

(3) The extensibility of GIS software is limited. The requirements for new functionalities and new technologies usually rise by using the system. Without changing source codes, it is not easy to add new functionalities or new interfaces for new technologies in order to integrate the proprietary GIS system with other information systems, or extend a local spatial information system to a regional or national spatial data infrastructure (SDI).

The World Wide Web has now established itself as one of the fastest growing technologies in the computer world. More and more application systems select the Web as the development platform. With the integration of Web and GIS technologies, Web-based GIS has been an active trend in GIS development. Using Web-based GIS, the data providers can publish and disseminate spatial information to the general public, and the general public can access and use it without the need to buy expensive GIS software and knowing the intricacy of GIS software and

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database management systems. Geographic information on the Web is a breakthrough in spatial information sharing (Pienaar, 1999), and resolves the first limitation.

In order to overcome the second limitation, a series of open specifications have been proposed by the OpenGIS Consortium (OGC). OGC is an international industry consortium of more than 340 companies, government agencies, and universities aimed at growing interoperability for technologies involving spatial information and location. Its mission is to promote the development and use of advanced open system standards and techniques in the area of geo-processing and related information technologies delivering spatial interface specifications that are openly available for global use. The Web Mapping Service (WMS), Web Feature Service (WFS) and Web Coverage Service (WCS) implementation specifications are three important OGC specifications for forest information systems.

WMS standardizes the way in which maps are requested by clients and the way that servers describe their data holdings (OGC, 2001), and is applicable to pictorial rendering of maps in a graphical format. Users can request maps from a WMS instance in terms of named layers and provided parameters such as the size of the returned map as well as the spatial reference system to be used in drawing the map. Based on the WMS services, maps from multiple WMS servers on the Internet can be overlaid for display.

WFS allows a client to retrieve and update geospatial vector data encoded in Geography Markup Language (GML) from multiple Web Feature Services (OGC, 2002). The Geography Markup Language is an XML encoding for modeling, transport and storage of geographic information including both the spatial and non-spatial properties of geographic features (OGC, 2003). Based on WFS services, feature level interoperability can be realized.

WCS serves to describe, request, and deliver multi-dimensional raster data over the World Wide Web (OGC, 2003), so that raster images can be accessed through a WCS service.

These OGC open specifications enable interoperability. As to extensibility, the Web service based architecture provides a good way to extend systems because Web services are modular, self-describing, self-contained, platform-independent applications which are accessible over the Web. Because Web service based application systems are loosely coupled, Web services can be added or removed flexibly.

There are already Web based GIS systems that are accessible to the general public, such as Wisconsin Department of Natural Resources, U.S. Fish and Wildlife Service, British Columbia's Public Internet Mapping Sites, but most of them are based on one commercial Web-based GIS software, and do not use Web services to integrate data provided by the other Web-based GIS servers.

The paper is intended to describe and discuss a prototype Web service based spatial forest information system using Open Source Software. Utilizing Web Map Services, the system can visualize the maps from different WMS servers which use WFS and WCS as data sources. As we know, the WFS consists of basic WFS and transactional WFS. The Users can get feature information about spatial data, and do QUERY and DISCOVERY operations via the basic WFS. The transactional WFS functions including INSERT, UPDATE and DELETE, which enable forest resources managers to do remote administration, will be the next step in the implementation. By the integration of WMS, WFS and WCS services, the Web service based spatial forest information system can fully use data from different servers, raise the management level of forest resources and provide sharing forest information to all levels of governments, environment agencies, academies, and the general public. Because it is a Web Service based system, it can be easily integrated into a larger spatial forest information system.

System development

System development should address the following questions: which application software should be used? How to secure data interoperability? How about the reliability and security of the software? How about the costs?

As more and more Open Source Software (OSS) systems have been developed or are being developed by individuals, academies, universities, or even commercial companies, OSS has covered operating systems, web servers, Web-based GIS applications and database management systems, and is becoming an alternative option to commercial solutions. In the GIS community, there are some commercial Web GIS and Open Source GIS software compliant to or implementing the WMS and WFS OGC specifications. ArcIMS, GeoMedia Web Map Professional, MapInfo MapXtreme of the commercial software camp, and UMN MapServer, GeoServer, Deegree of the Open Source community, are all compliant to or implementing WMS and WFS implementation specifications. As to data interoperability, there is not much difference because all of them are compliant to the OGC WMS and WFS specifications. As to reliability and security, Boulanger (2005) pointed out that in general both free and open-source software (FOSS) and proprietary systems are roughly equivalent in terms of security and reliability based on analysis on availability of source code, software defect levels, vendor-neutral studies and comparison of the development process. Thus the Total Cost of Ownership (TCO) will be the main consideration of selecting system development software. Usually TCO includes five categories: original costs of the computer and software, hardware and software upgrades, maintenance, technical support and training. Regarding these categories, there is not much difference between commercial software and open source software except for the original costs of software and software update. For commercial software, users have to pay for licenses and update fees while open source software is available at a low price or even no cost.

As forests are in dynamically changing status, such as planting, thinning, maturing, logging, it is appropriate to manage the spatial forest data in local counties so that the data can be updated as fast as possible. Based on this consideration, building a distributed Web service based spatial forest information system is necessary. Every county level forest administration unit should have an application service node which will be part of the upper level system, thus Web service based application in a county can distribute the up-to-date spatial forest data, and be integrated into a regional or national forest information system. As there are many county level forest administration units, if we choose commercial proprietary software, commercial license fees will cost a large amount of money whereas open source software can be freely downloaded from the Internet, and the source codes can be modified and redistributed. Open source software is an alternative choice for those who have limited financial budget to build application systems. Some geospatial related open source soft-

ware packages are mature enough to build practical web applications (Raghavan *et al* 2002, 2003; Anderson 2003). Although these web applications have proved that OSS is an alternative solution to proprietary systems, they are still single web applications, and do not provide interoperability. Because of the requirements of interoperability and extendibility, we chose OSS compliant to WMS and WFS specifications to build a Web service based spatial forest information system.

Web Service based system architecture

A Web service is an interface that describes a collection of operations that are network-accessible through standardized XML messaging (Gottschalk 2002). It provides a standard means of interoperating among different software applications running on a variety of platforms and/or frameworks. A Web service server can provide a Web service to the client; at the same time it can be a web client to request web services from other Web service servers. Application integration through Web services can yield flexible coupled business systems. Using Web services to build application systems has several advantages (Jablonski *et al.* 2004):

(1) Web services enable interoperability. Web service based applications comply with a set of standardized technologies. As long as service providers and clients follow them, interoperability is enabled.

(2) Web services leverage existing technologies. Web services basically encompass only the call infrastructure. How the Web service functionality is implemented is not a matter of concern. Therefore the business functionality may be implemented using any language (e.g. PERL script, C language, Java language).

(3) Web services promote reuse of codes, shorten system development time and reduce the costs needed for system development. Instead of writing everything from scratch, developers make full use of the codes and application through coupling the existing Web service applications.

The Web service based architecture consists of three major parties: service requester, service provider, and service integration server. A service provider creates a Web service and its service definition that describes its capabilities. The service integration server is responsible for registering Web services and application business logic. Through the service integration server, the service requester can get information from Web service providers. Fig. 1 shows the relationship of the three parties.

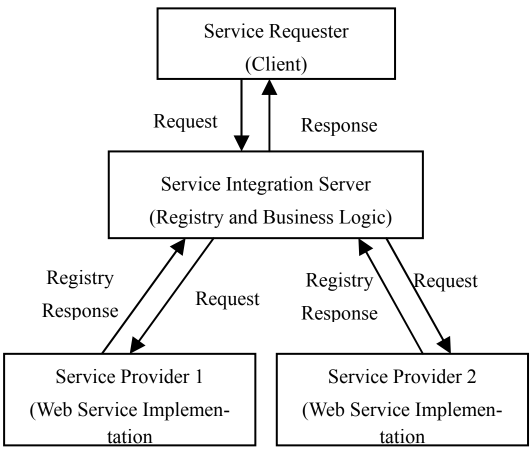

Fig. 1 Web Service based Architecture

From the implementation point of view, the Web service based spatial information system platform architecture (Fig. 2) can be divided into four tiers: Client Tier, Web Tier, Application Server Tier and Back-end Tier. At the Client Tier, the Web browser or the client application handles the Web presentation in terms of HTML pages; the Web Tier can work with different application servers and is responsible for the HTTP communication and generation of the application presentation, so the HTTP server and the scripting environment are located in this tier; the Application Server Tier contains the business logic of application servers; the Back-End Tier contains the database management system or flat files that are needed by application servers. System communication is based on TCP/IP and HTTP protocols.

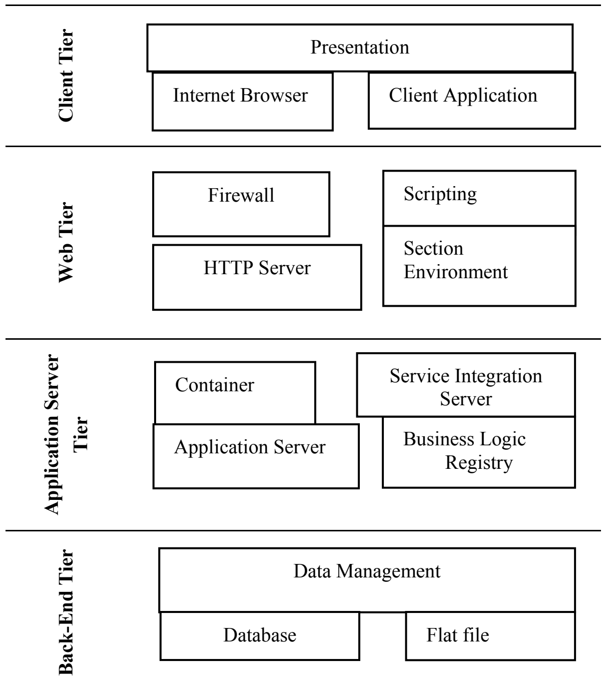

Fig. 2 Four-Tier Web Platform architecture

System prototype

We developed a prototype system of Web service based spatial forest information system for Xixia County, Henan province, China. Xiaxia County is in the west part of Henan province, and its forest areas cover more than 70% of its whole area. Forest and forest related products are important industries in Xixia County. The system was aimed at sharing spatial forest information, providing an online guide map to forest travelling routes, and facilitating forest resources management. As the financial budget for forest resources management is limited, it is almost impossible to build systems with proprietary Web-based GIS software. Therefore we chose to use the Open Source GIS packages Deegree and UMN MapServer, which are compliant to OGC open specifications, to build Web service based spatial forest information system instead of proprietary solutions.

Data preparation

Data sources include: the 1:250,000 county boundary vector data, the 1:250,000 roads and rivers maps，the 1:250,000 travelling route and site maps，the 1:250,000 forest inventory data which

includes tree species, topographical information, land use, ownership, soil type, and other important forest parameters, and remote sensing satellite imagery (captured on September 25, 2002) provided by the Xixia Forest Bureau.

System Implementation

We chose SuSE linux as the operating system. As to the Client Tier, we chose FireFox as Web browser and iGeoPortal as the web map client application; in the Web Tier, the Apache HTTP server was used as Web server; in the application server aspect, we selected Tomcat as servlet container, UMN MapServer and Deegree as the application servers to provide Web services. Deegree was also used as the service integration server because in addition to provide local Web services it can integrate Web services from UMN MapServer at the same time. In the Back-End Tier, PostgreSQL/PostGIS and flat files were selected as data sources. The following gives a brief introduction to these components.

(1) Client Tier: Firefox, the open source solution developed by Mozilla, is hitting the number two spot with a 10.28 percent share of the Internet Web browser market in April, 2005. It is easy to use and customize. The web map client application iGeoPortal offers a user-friendly interface to visualize the map layers that come from Web service providers through a standard web browser. It returns the rendered maps no matter the WMS instances are from a commercial camp or the open source community.

(2) Web Tier: Apache has been the most popular web server on the Internet since April 1996. The February 2005 Netcraft Web Server Survey found that more than 68% of the web sites on the Internet are using Apache, thus making it more widely used than all other web servers combined. It is a robust, commercial grade, standards-compliant, and feature-rich HTTP server.

(3) Application Server Tier: Tomcat is a free, open-source implementation of Java Servlet and JavaServer Pages technologies developed under the Jakarta project at the Apache Software Foundation. It is used as a servlet container for the Deegree packages. UMN MapServer was originally developed at University of Minnesota (UMN) in the ForNet-project in cooperation with NASA and Minnesota Department of Natural Resources. It is an open source development environment for building spatially enabled Internet applications. The software builds upon other popular open source or freeware systems like Shapelib, FreeType, Proj.4, GDAL/OGR and others. It is not a full-featured GIS system, but it does provide the core functionality to support a wide variety of web applications and supports WMS and WFS. Deegree is a Java framework product for the implementation of local and web based GIS applications. Its interfaces and architecture guarantee optimized interoperability due to the standards of the OGC. Deegree packages provide WMS, WFS, and WCS services. Although UMN MapServer, written in C language, is based on Common Gateway Interface (CGI) technology and Deegree, written in Java language, is based on Servlet technology, they can work together in a Web service based environment because both of them are compliant to the OpenGIS Consortium (OGC) WMS and WFS specifications. Considering the data update and timeliness, we set up two application servers: the forest server as the main application server and the service integration server, and the geospatial information server as second application server. Both servers use PostgreSQL/PostGIS database as vector data source.

The geospatial information server implemented with UMN MapServer provides Web services for boundary, road and river information, and is maintained by the geospatial information center. When compiling UMN MapServer, OGC WMS and WFS support options should be enabled. After installation of UMN MapServer, we had to create the configuration MapFile file, the basic configuration mechanism for the UMN Mapserver. For detailed information on objects in the configuration file, see the MapFile reference. Compiled with the PostGIS option, UMN MapServer can directly connect to the PostgreSQL/PostGIS database.

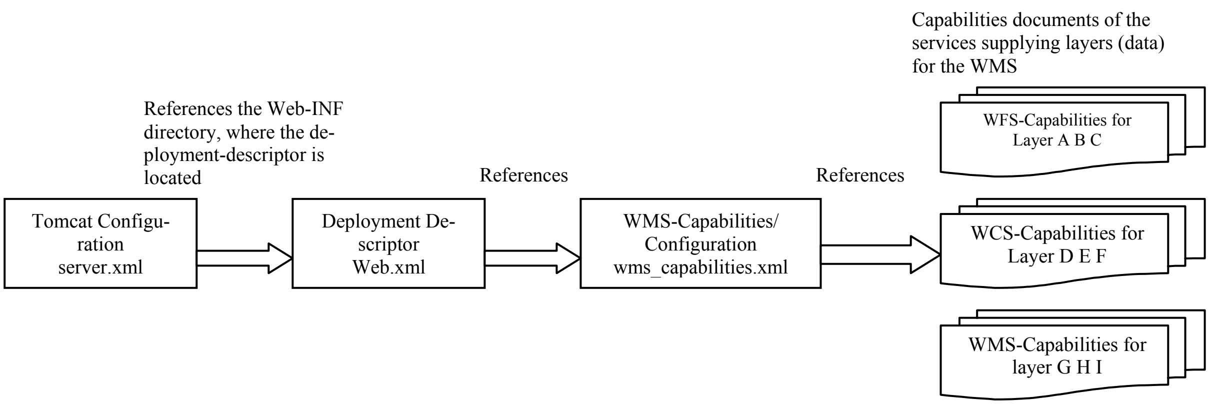

Fig. 3 Deegree WMS configuration (taken from the Deegree Web Map Server configuration document)

The forest server was implemented with the Deegree packages. As an application server, it provides Web services for forest inventory information, travelling route map and remote sensing imagery, and is maintained by the local forest bureau. The Deegree packages include a series of services: WMS, WFS, and WCS. The WMS uses WFS and WCS as data sources for the map rendering. Vector data including forest inventory and travelling route maps are implemented with WFS. Remote sensing imagery can be accessed through WCS. The Deegree packages must be registered to the Tomcat servlet container to provide Web services. We had to add registry information to Tomcat and modify the configuration files of the Deegree package to suit to the location of the data sources. Fig. 3 shows the Deegree WMS configuration. Deegree WFS uses JDBC to connect to the PostgreSQL/PostGIS database. Because the Deegree WMS has the capabilities to integrate Web services from other service provid-

ers, the forest server also acts as a service integration server to integrate Web services from UMN MapServer.

(4) Back-End Tier: PostGIS and flat files were used to store spatial forest data. PostgreSQL is one of the most advanced open source object relational database management systems available (Worsley, 2002). It offers enterprise level features such as data backup, disaster recovery, and database replication. PostGIS adds support for geographic objects to the PostgreSQL object-relational database. It spatially enables the PostgreSQL server, allowing it to be used as a backend spatial database for geographic information systems. PostGIS includes support for GiST-based R-Tree spatial indexes and functions for basic analysis of GIS objects. All vector data were converted into tables of the PostGIS database. Remote sensing imagery was stored as flat files on the forest server. Considering response time, it was split into tiled images with different spatial resolutions using the tool provided by the Deegree packages.

System Features

The prototype system of the Web service based spatial forest information system for Xixia County enables users to access spatial forest information and facilitates forest resource management. Because it is based on Web service based architecture, the system is extensible and scalable. It is easy to add or remove Web services, and extend to a regional or national system.
Users can interactively view the map layers that come from Web service instances by the Web map client application iGeoPortal and the web browser (cf. Fig. 4). With the interface of iGeoPortal, users send requests to the Web server, and the Web server processes the requests and communicates with the service integration server. The service integration server interacts with application servers to get maps, and then sends results to the Web map client iGeoPortal. iGeoPortal is responsible for visualizing the map layers. Web services from the service integration server have to register to iGeoPortal so that it can return rendered maps. According to the objective of the application system, Web services can be combined to form a theme. For example, Web services from UMN MapServer and Deegree form the Xixia theme. It provides the interactive user-friendly interface to the users. Users do not need to keep track of the application servers or even recognize which application servers are running behind the service integration server. Through the interface of iGeoPortal, users can access the spatial forest information system at any place and at any time via the Internet, and operate basic GIS functions including zoom in, zoom out, pan and query:

Zoom in, zoom out and pan
Users can select a theme from the theme list, and data layers pertaining to it will be listed. According to the user's selection, different data layers from different application servers can be overlaid to render a composite map. The composition of map layers can show the spatial relationship of different features.

Fig. 4 shows the composition map of rivers map, roads map and boundary map from the geospatial information center server and traveling site map, traveling route map, forest inventory map, and remote sensing image as a background from the forest server. The Zoom/pan capability allows the user to view interactively the displayed layers in great detail or choose different parts of maps for display.

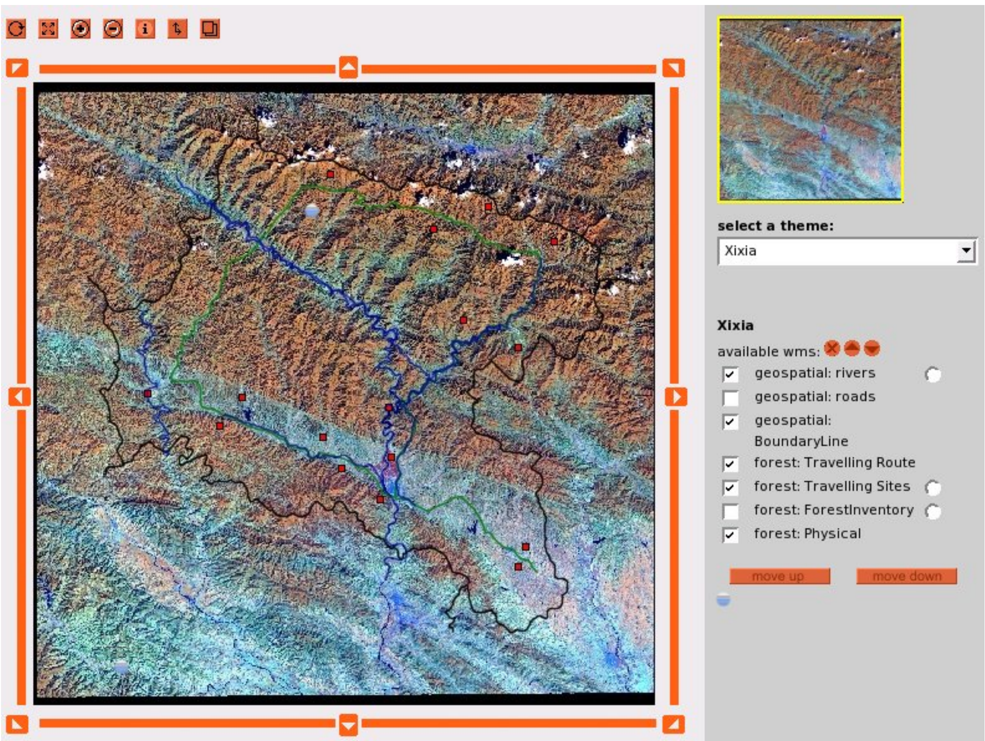

Fig. 4 The interface of the prototype system

Query
Data query is based on the geographical location of the selected map layer. On the right-lower part of Figure 4, the radio button behind the map layer's name means that this layer is queryable.

User can select only one queryable layer to query attribute information at a time. As we know, forest inventory data contains a lot of information, such as tree species, diameter for breast height, tree height, age level, origin, dominant tree species composition, soil type, soil texture, slope, aspect, management type, forest type, plot number, owner, etc. Some of them are confidential. Service providers can restrain the items of attributes that the users can access by making the sensible data attributes invisible. After the selection of the queryable layers, users can query information by clicking the feature of forest inventory, travelling sites, or rivers, and then the corresponding attribute information will appear in a new web page. Fig. 5 shows the query result window of the forest inventory layer which indicates the queried results of a forest plot including the index number of the plot, the number of the plot, the altitude of the plot, the village code number and the land cover type of the plot.

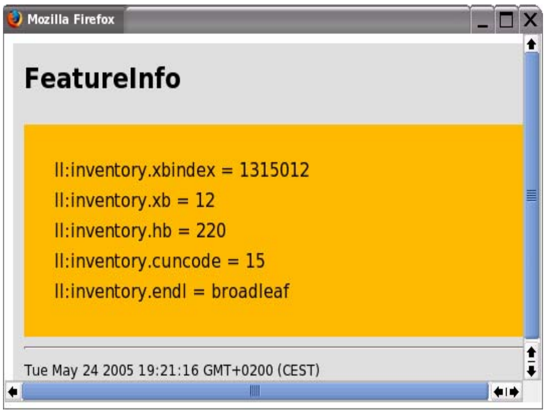

Fig. 5 Query result window

Online integration

If the user needs an additional Web service that is not integrated into the system in advance, that Web service can be integrated online by entering the Universal Resource Locator (URL) of the Web Map Service instance (cf. Fig. 6). This provides a flexible way to integrate Web services into the system.

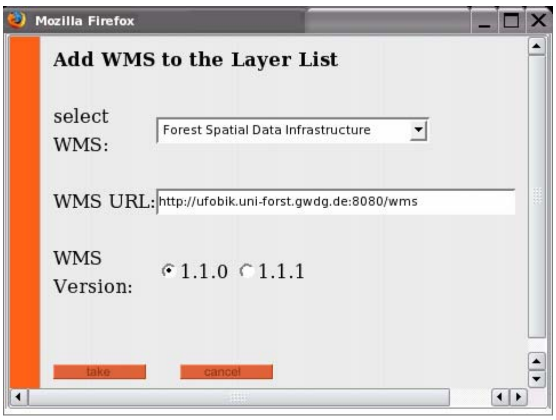

Fig. 6 WMS Online Integration

Conclusion

The prototype system described in this paper demonstrates that a Web service based spatial forest information system using open source software promotes spatial forest information sharing at a cost-effective way, enables the users to access and integrate spatial forest information, and facilitate forest resource management. Users can easily access and interact with the spatial forest information by Web browsers. The Web service based architecture ensures code reuse, shortens development time and reduces costs, and makes the system extendable and scaleable. The individuals and organizations in need of spatial forest information can easily integrate the available services into their own Web service based systems. Moreover, the prototype system can be extended into a regional or national spatial forest information system. The system developed with open source software is very suitable for organizations that have limited financial budget for spatial data sharing, especially in developing countries. Integrating OSS Web service based applications to build spatial information systems is a promising alternative to solutions based on commercial products.

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